THE BELL SYSTEM TECHNICAL JOURNAL
Vol. 53, No. 6, July–August 1974
Printed in U.S.A.

B.S.T.J. BRIEF

Stripline Downconverter With Subharmonic Pump

By M. V. SCHNEIDER and W. W. SNELL, JR.

(Manuscript received April 19, 1974)

I. INTRODUCTION

The process of frequency conversion and its applications are well known and have been extensively treated in the literature.[1–3] The conversion is usually performed by pumping a nonlinear resistive or reactive element embedded in a linear network and by extracting the sum or difference frequencies that are generated by the signal and the pump frequency. The purpose of this Brief is to describe a novel thin-film converter* which has the following properties:

(*i*) The pump frequency required for efficient upconversion or downconversion is a submultiple of that needed in conventional frequency converters.
(*ii*) The circuit does not require a dc return path.
(*iii*) The separation of the signal and the pump frequency is readily obtained and the loss in the signal path is small.

The new converter consists of two stripline filters and two Schottky barrier diodes, which are shunt mounted with opposite polarities in a strip transmission line. The conversion loss measured at a signal frequency of 3.5 GHz is 3.2 dB for a pump frequency of 1.7 GHz and 4.9 dB for a pump frequency of 0.85 GHz. The circuit looks attractive for use at millimeter-wave frequencies where stable pump sources with low FM noise are not readily available.

* After the manuscript for this Brief was completed, it was learned that M. Cohn, J. E. Degenford, and B. A. Newman at Westinghouse Electric Corp., Baltimore, Md., have begun independent work along similar lines.

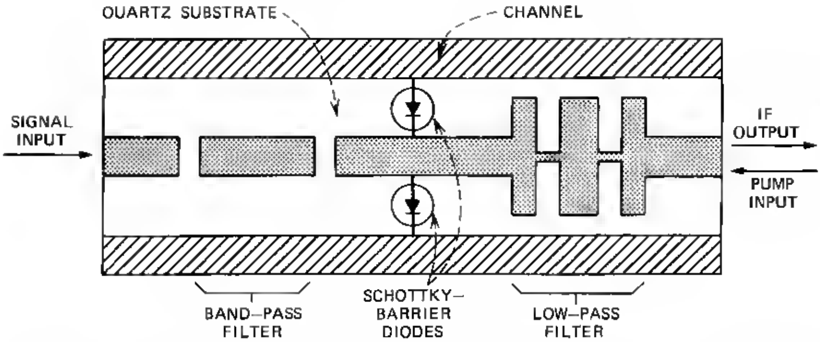

Fig. 1—Microstrip conductor pattern on quartz substrate in a metal channel. The diode pair is shunt mounted with opposite polarities to the ground on opposite sides of the strip transmission line.

II. DESCRIPTION OF STRIPLINE CIRCUIT

A top view of the stripline conductor pattern used in the down-converter is shown in Fig. 1 and a cross-sectional view is shown in Fig. 2. A strip transmission line is used because the conversion from the hybrid TEM mode to the first-order waveguide mode (longitudinal section magnetic mode) is substantially reduced compared to the conversion obtained with other transmission line circuits such as microstrip lines.[4] This approach eliminates noise contributions from undesired bands near the harmonics of the pump frequency.

The conductor pattern consists of a 50-ohm line section at the signal input, a half-wavelength resonator for the bandpass filter, a five-element low-pass filter, and a 50-ohm line section for the pump input and the IF output. Two Schottky-barrier diodes with opposite polarities are connected to the section between the filters at opposite

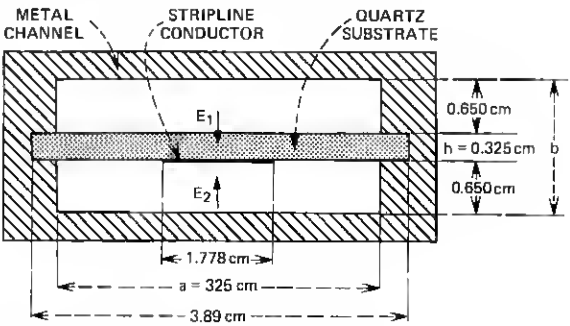

Fig. 2—Cross-sectional view of shielded stripline with symmetrically suspended quartz substrate and stripline conductor.

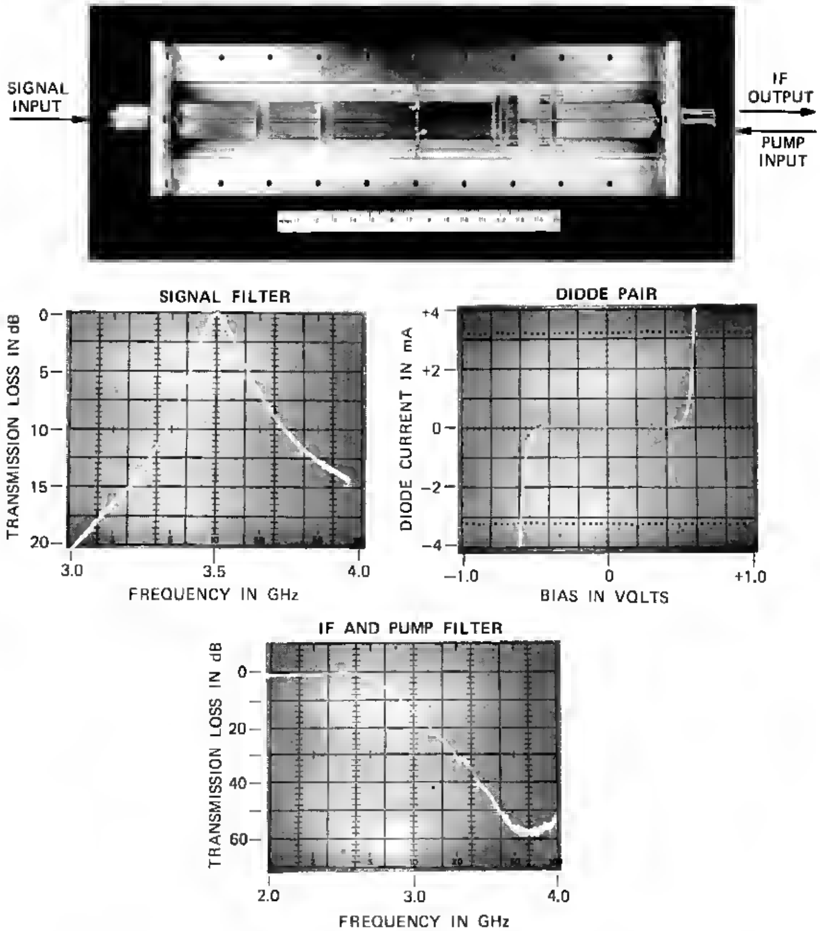

Fig. 3—Photograph of downconverter showing top view of stripline conductor pattern in rectangular channel. The characteristics of the band-pass filter, the low-pass filter, and the diode pair are displayed at the bottom of the photograph.

sides of the stripline conductor. Coupling to undesired waveguide modes above the cutoff frequency of the metal channel is suppressed because the electric field vectors in the top and the bottom section of the stripline are of opposite polarity as indicated in Fig. 2. A photograph of the downconverter is shown in Fig. 3. The figure also shows the measured transmission characteristics of the stripline band-pass filter and low-pass filter, and also the current-voltage characteristics of the diode pair. The current-voltage characteristics of the diode

pair are symmetrical with respect to the origin. This results in a current waveform that has only odd-order harmonics and a conductance waveform with even-order harmonics. The second feature comhined with the low conversion to waveguide modes results in a converter that has a good conversion loss and a low noise figure for suhharmonic pumping

III. PERFORMANCE OF STRIPLINE CONVERTER

The measured single-sideband noise figure for the stripline converter of Fig. 3 is plotted in Fig. 4 as a function of the signal frequency ω_s for $m = 2$ and $m = 4$, where m is the harmonic integer defined by $m = (\omega_{signal} \pm \omega_{IF})/\omega_{pump}$. The noise figure of the 100-MHz IF amplifier is 1.7 dB. The total single-sideband noise figure, including the IF amplifier noise at a signal frequency of 3.455 GHz, is 4.9 dB for $m = 2$ and 6.6 dB for $m = 4$. The corresponding conversion loss is 3.2 dB for $m = 2$. This result approaches the theoretically predicted loss of 2.1 dB for the diode pair with a series resistance $R_s = 2$ ohms and a zero bias capacitance of $C_0 = 0.45$ pF for each diode.[5]

The new harmonically pumped stripline circuit can be readily scaled to higher microwave frequencies and particularly to millimeter-wave frequencies where solid-state oscillators are only availahle at suhharmonics of the local oscillator frequency. The hasic design principles discussed in this paper can also be applied to other con-

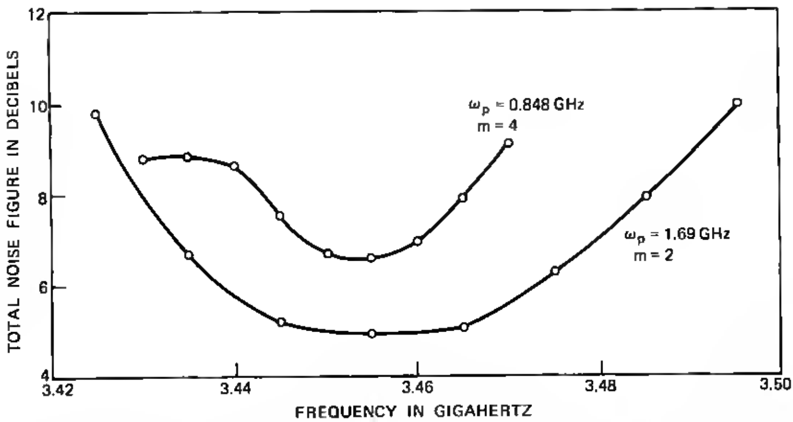

Fig. 4—Single-sideband noise figure including IF amplifier noise for downconverter pumped at the second subharmonic ($m = 2$) and the fourth subharmonic ($m = 4$). The noise figure of the 100-MHz IF amplifier is 1.7 dB.

verters in the electromagnetic spectrum, such as upconverters, harmonic generators, and parametric amplifiers.

REFERENCES

1. C. T. Torrey and C. A. Whitmer, *Crystal Rectifiers*, MIT Radiation Laboratory Series, *15*, New York: McGraw Hill, 1948.
2. C. Dragone, "Amplitude and Phase Modulations in Resistive Diode Mixers," B.S.T.J., *48*, No. 6 (July-August 1969), pp. 1967–1998.
3. A. A. M. Saleh, *Theory of Resistive Mixers*, Research Monograph No. 64, Cambridge, Mass.: Massachusetts Institute of Technology Press, 1971.
4. M. V. Schneider and B. S. Glance, "Suppression of Waveguide Modes in Strip Transmission Lines," Proc. IEEE, to be published.
5. C. Dragone, private communication.

Fiber Ribbon Optical Transmission Lines

By R. D. STANDLEY

(Manuscript received April 2, 1974)

This brief proposes the use of fiber ribbons consisting of a linear array of fibers embedded in a thin, flexible supporting medium as components of a cable for fiber transmission systems. With the progress that has been made in drawing low-loss fibers, the physical form used to cable the fibers has become a truly relevant problem and is presently being pursued at several laboratories.

Figure 1 shows some of the structures of interest. The value of ribbons in a transmission cable was initially conceived as relating well to planar technology for connector and repeater circuitry fabrication. A natural layout for repeater electronics is an input consisting of a linear array of detectors with a similar emitter array for the output.

Fiber ribbons should also be easier to handle than conventional bundles. In the event of cable breakage, the ribbon resolves the problem of fiber identification; coding is simple. Ribbons may be easily stacked to form higher-capacity cables. The geometry lends itself well to connector design. For example, suppose the supporting medium to be some sort of plastic. To make fiber separation easy, we cut the ribbon, then we dissolve a portion of the supporting medium to free the fiber ends. The ends are then placed in the connector, which is finally recoated with the plastic.

verters in the electromagnetic spectrum, such as upconverters, harmonic generators, and parametric amplifiers.

REFERENCES

1. C. T. Torrey and C. A. Whitmer, *Crystal Rectifiers*, MIT Radiation Laboratory Series, *15*, New York: McGraw Hill, 1948.
2. C. Dragone, "Amplitude and Phase Modulations in Resistive Diode Mixers," B.S.T.J., *48*, No. 6 (July-August 1969), pp. 1967–1998.
3. A. A. M. Saleh, *Theory of Resistive Mixers*, Research Monograph No. 64, Cambridge, Mass.: Massachusetts Institute of Technology Press, 1971.
4. M. V. Schneider and B. S. Glance, "Suppression of Waveguide Modes in Strip Transmission Lines," Proc. IEEE, to be published.
5. C. Dragone, private communication.

Fiber Ribbon Optical Transmission Lines

By R. D. STANDLEY

(Manuscript received April 2, 1974)

This brief proposes the use of fiber ribbons consisting of a linear array of fibers embedded in a thin, flexible supporting medium as components of a cable for fiber transmission systems. With the progress that has been made in drawing low-loss fibers, the physical form used to cable the fibers has become a truly relevant problem and is presently being pursued at several laboratories.

Figure 1 shows some of the structures of interest. The value of ribbons in a transmission cable was initially conceived as relating well to planar technology for connector and repeater circuitry fabrication. A natural layout for repeater electronics is an input consisting of a linear array of detectors with a similar emitter array for the output.

Fiber ribbons should also be easier to handle than conventional bundles. In the event of cable breakage, the ribbon resolves the problem of fiber identification; coding is simple. Ribbons may be easily stacked to form higher-capacity cables. The geometry lends itself well to connector design. For example, suppose the supporting medium to be some sort of plastic. To make fiber separation easy, we cut the ribbon, then we dissolve a portion of the supporting medium to free the fiber ends. The ends are then placed in the connector, which is finally recoated with the plastic.

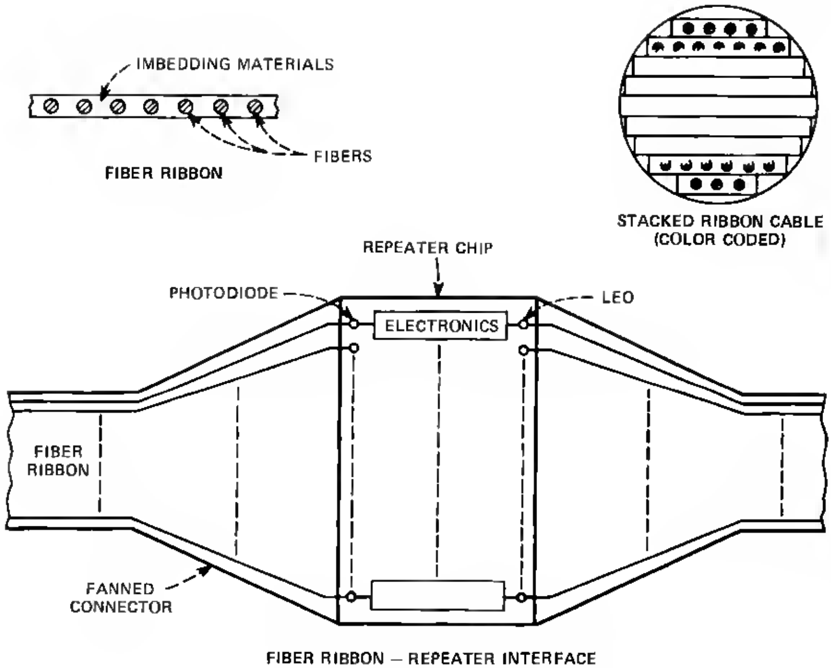

Fig. 1—Some fiber ribbon structures.

Many forms can be envisioned for the connector. For example, consider a glass plate whose refractive index is less than that of the fiber. Using conventional photolithographic techniques, one can etch channels in the glass. The fibers may then be placed in the channels and covered with a second glass plate or a plastic similar to the ribbon support. The output end of the connector can be polished to clean up the fiber ends if necessary.

Finally, the manufacture of ribbons should be straightforward. Two methods are described in the literature.[1,2]

As stated previously, the purpose of this brief has been to describe concepts of fiber ribbon transmission line accessories. It is recognized that practical difficulties will ensue when attempting to reduce any of the concepts to the hardware stage. For example, mechanical tolerances, which will generally be dependent upon the fiber core diameter, are of prime importance in any hardware for any fiber optic transmission line. However, we believe that the naturally planar form of the fiber ribbon, associated connectors, and circuitry described above

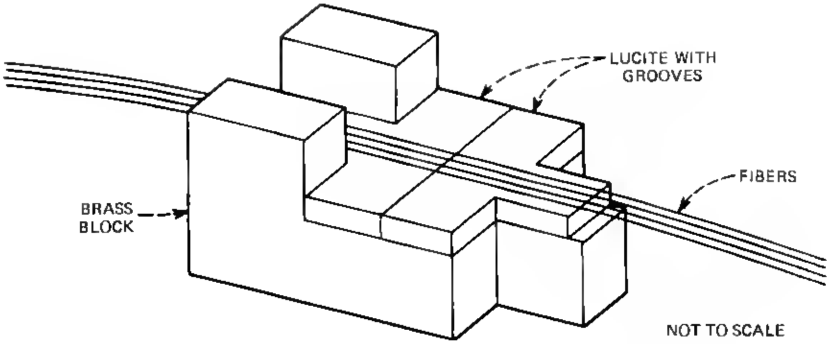

Fig. 2—Grooved lucite planar connector for fiber ribbon transmission line.

would permit excellent dimensional control. Experimental work would be necessary to define quantitative limits.

Some years ago we did experiments on fiber connectors having the form shown in Fig. 2. Here grooves were hot-pressed into lucite blocks using fibers of the same size as those to be mounted as templates. Fibers were then inserted into the grooves and held in place by cement. Typical loss achieved upon disassembly and reassembly was 1 dB $\pm$ 0.5 dB, which was considered acceptable for such a crude structure. In another experiment, one lucite block was made mechanically movable to form a single-pole, double-throw switch; loss variation upon operating the switch was again about 1 dB.

The prospects for near-term use of optical fibers in communications systems are indeed good; what is hoped is that the above concepts will stimulate others in the pursuit of a useful and economic cabling method and, thus, lead to a more rapid application of fibers in practical systems. Recently, a method was proposed for splicing fiber ribbons of the type described above.[3]

REFERENCES

1. U. S. Patents No. 3,247,755 and No. 3,272,063.
2. M. Borner, "Fiber Component Design," Seminar on Optical Fibers in Telecommunications, April 9–13, 1973, Bologna, Italy.
3. E. A. J. Marcatili, U. S. Patent No. 3,789,099, "Methods for Splicing Optical Fibers."